Supporting information for

ZIP-8/Ag-based Size-selective SERS Nanoplatform for Ultrasensitive Urea Detection in Milk Samples: Effects of Analyte Molecular Dimensions on Adsorption Capacity and Sensing Performance

Dao Thi Nguyet Nga[a,1], Quan Doan Mai[a], Linh Ho Thuy Nguyen[d,e], Tan Le Hoang Doan[d,e]
Vu Thi Kim Oanh[b], Ta Ngoc Bach[b], Vu Dinh Lam[b], Ha Anh Nguyen[a,*,1], Anh-Tuan Le[a,c,**]

[a]*Phenikaa University Nano Institute (PHENA), Phenikaa University, Hanoi 12116, Vietnam*

[b]*Institute of Materials Science (IMS) and Graduate University of Science and Technology (GUST), Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet, Hanoi 10000, Vietnam*

[c]*Faculty of Materials Science and Engineering (MSE), Phenikaa University, Hanoi 12116, Vietnam*

[d]*Center for Innovative Material and Architectures, Ho Chi Minh City, Vietnam*

[e]*Vietnam National University-Ho Chi Minh City, Ho Chi Minh City, Vietnam*

Corresponding authors:

*anh.nguyenha@phenikaa-uni.edu.vn (H.A.Nguyen)

**tuan.leanh@phenikaa-uni.edu.vn (A.T.Le)

[1] D.T.N. Nga and H.A. Nguyen contributed equally to this work

Calculation of limit of detection (LOD) and limit of quantification (LOQ)

The standard curve of linear detecting range was given as:

$$Y = A + B \times Log(X) \tag{1}$$

where A and B are intercept and slope of regression equation obtained through the plot of the logarithmic SERS intensity (Y) – logarithmic concentration (X).

The LOD is calculated using the following equation [1]:

$$LOD = 10^{\left[(Y_{blank} + 3SD)/Y_{blank} - A\right]/B} \tag{2}$$

The LOQ is calculated as

$$LOQ = 10^{\left[(Y_{blank} + 10SD)/Y_{blank} - A\right]/B} \tag{3}$$

where Y_{blank} and SD are the SERS signal and the standard deviation of blank sample, respectively.

SD is calculated via the well-known formula:

$$SD = \sqrt{\frac{1}{n-1} \times \sum_{i}^{n} (x_i - x_{average})^2} \tag{4}$$

where x_i if the "i" sample of the series of measurements, $x_{average}$ is the average value of SERS signal obtained from the blank sample repeated n times.

Calculation of relative standard deviation (RSD)

The RSD value of repeatability and reproducibility is calculated via the well-known formula:

$$\text{RSD} = \frac{SD \times 100}{x_{average}} \tag{5}$$

where SD is the standard deviation that calculates using equation 4 and $x_{average}$ is the average value of SERS signal obtained from each measurement.

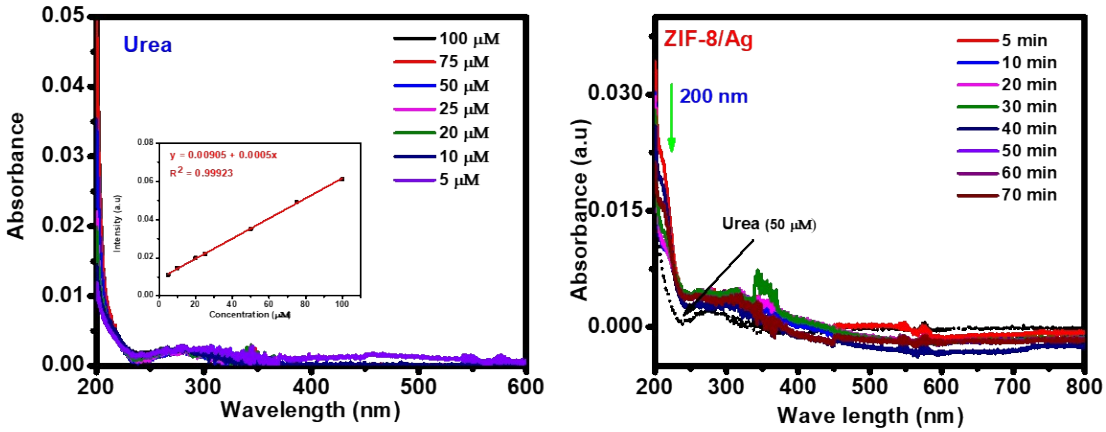

Figure S1. (a) Absorption spectra of urea at different concentrations and linear plot; (b) Absorption spectra of the mixture containing 10 µL of urea (5 mM) added into 2.0 mL of ZIP-8/Ag solution (50 ppm) over an incubation of 70 min.

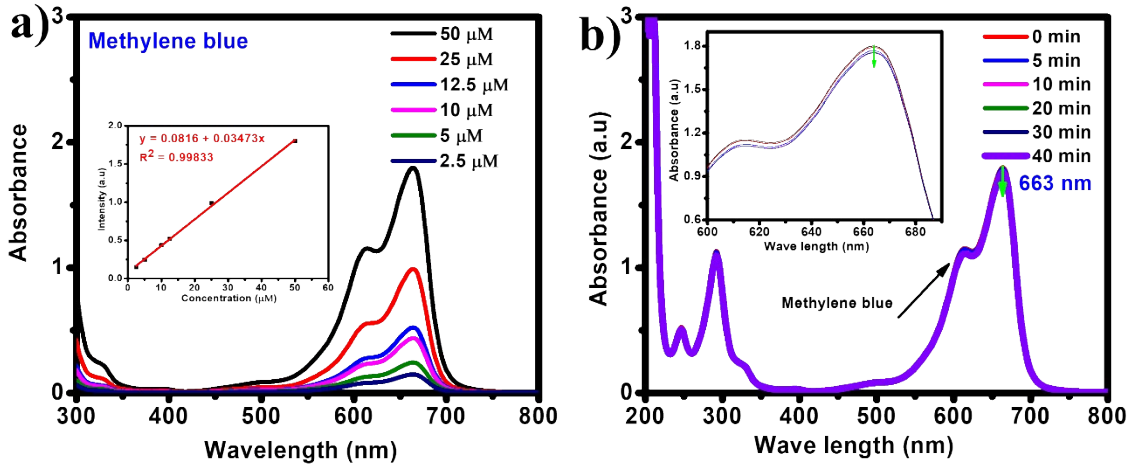

Figure S2. (a) Absorption spectra of MB at different concentrations and linear plot; (b) Absorption spectra of the mixture containing 10 µL of MB (5 mM) added into 2.0 mL of ZIP-8/Ag solution (50 ppm) over an incubation of 40 min.

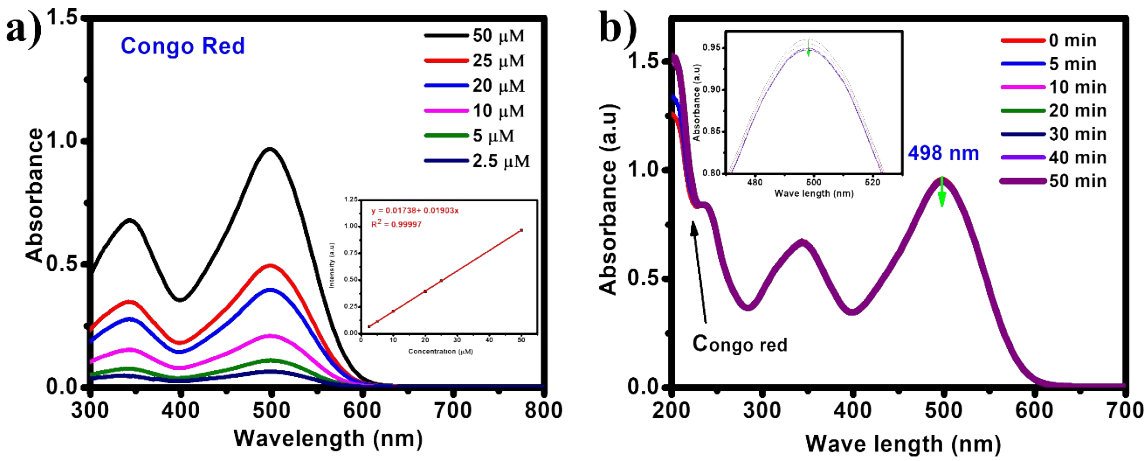

Figure S3. (a) Absorption spectra of CR at different concentrations and linear plot; (b) Absorption spectra of the mixture containing 10 µL of CR (5 mM) added into 2.0 mL of ZIP-8/Ag solution (50 ppm) over an incubation of 60 min.

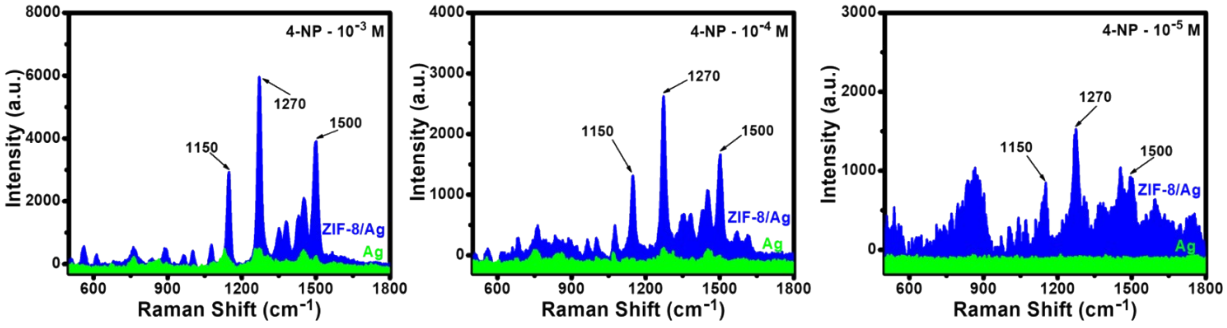

Figure S4: SERS spectra of 4-NP (10^{-3} M – 10^{-5} M) on Ag and ZIF-8/Ag

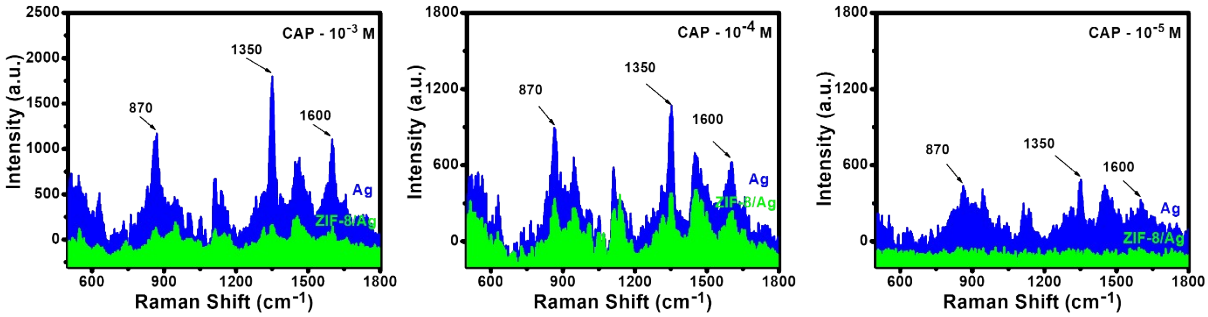

Figure S5: SERS spectra of CAP (10^{-3} M – 10^{-5} M) on Ag and ZIF-8/Ag

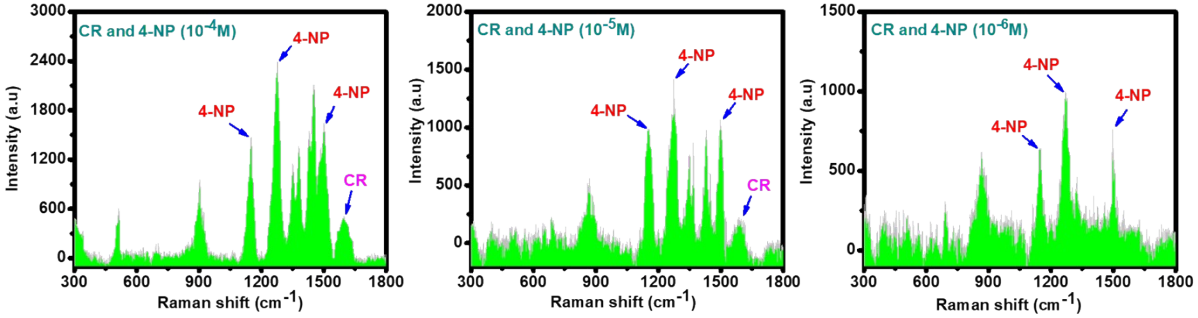

Figure S6. SERS spectra of solutions containing 4-NP and CR at 10^{-4} M, 10^{-5} M, and 10^{-6} M on ZIF-8/Ag

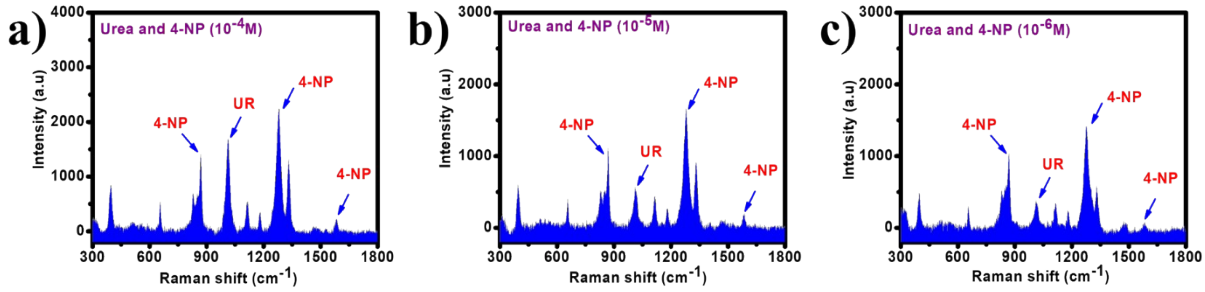

Figure S7. SERS spectra of solutions containing Urea and 4-NP at (a) 10^{-4} M, (b) 10^{-5} M, and (c) 10^{-6} M on ZIF-8/Ag

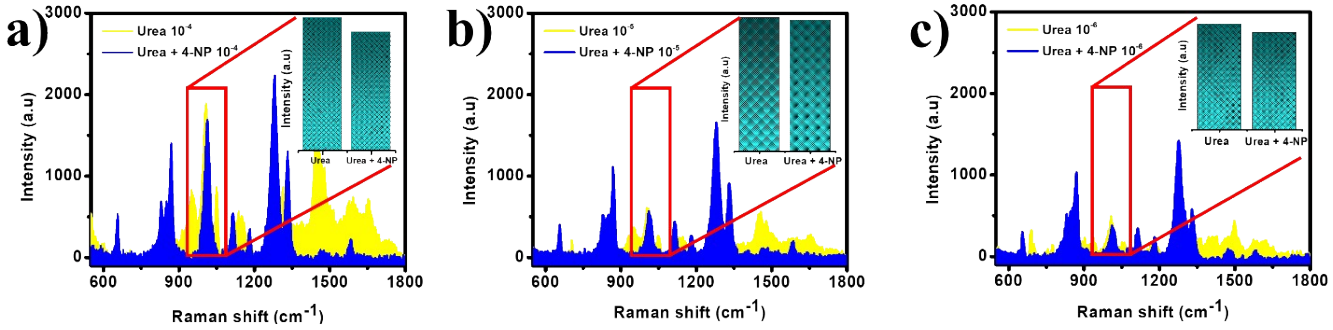

Figure S8. SERS intensities of Urea and Urea + 4-NP (a) 10^{-4} M, (b) 10^{-5} M, and (c) 10^{-6} M at characteristic peaks on ZIF-8/Ag

Table S1. Raman assignments of ZIP-8 [2]

Frequency (cm-1)	Band assignment
685	τ imidazolium ring
836	Imidazolium ring puchering, δ $H_{(out\ of\ plane)}$
953	δ C-$H_{(out\ of\ plane)}$ (C2-H)
1022	δ C-$H_{(out\ of\ plane)}$
1146	ν C-N
1180	ν C-N, N-H wag
1348	δ CH_3
1460	δ C-H

1500	ν C-N, N-H wag
1510	N C-H (imidazolium ring)
2924	N C-H (imidazolium ring)

Table S2. Practicability of ZIP-8/Ag based SERS sensor urea detection in milk samples

Spiked concentration (M)	Detected concentration (M)	Recovery rates (%)
10^{-5}	1.15×10^{-5}	115
10^{-6}	1.03×10^{-6}	103
10^{-7}	9.1×10^{-6}	91
10^{-8}	8.7×10^{-6}	87

Table S3. Raman bands of solid 4-nitrophenol [3]**.**

Raman (cm^{-1})	**Assignment**
1586	Ring stretch
1520	NO_2 antisymm. stretch
1500	C-H ip bend
1338	Ring stretch
1284	C-H ip bend
1172	C-H ip bend
1070	CCC bend

870	NO_2 bend
636	CCC bend

References

[1] R. Chen, H. Shi, X. Meng, Y. Su, H. Wang, Y. He, Dual-Amplification Strategy-Based SERS Chip for Sensitive and Reproducible Detection of DNA Methyltransferase Activity in Human Serum, Analytical Chemistry 91(5) (2019) 3597-3603.

[2] S. Tanaka, K. Fujita, Y. Miyake, M. Miyamoto, Y. Hasegawa, T. Makino, S. Van der Perre, J. Cousin Saint Remi, T. Van Assche, G.V. Baron, J.F.M. Denayer, Adsorption and Diffusion Phenomena in Crystal Size Engineered ZIF-8 MOF, The Journal of Physical Chemistry C 119(51) (2015) 28430-28439.

[3] M. Maurizio, SERS monitoring of the catalytic reduction of 4-nitrophenol on Ag-doped titania nanoparticles, Applied Catalysis B: Environmental, 146 (2014), 147-150.